EMUS

BATTERY MANAGEMENT SYSTEM

User's manual *Revision 1*

In this user's manual you will find a list of characteristics, setup and installation steps and recommendations for the EMUS Battery Management System. This document should be read before setting up your EMUS BMS.

JSC Elektromotus, 2011

Table of Contents

Introduction 2
System structure 2
Standard package contents 3
Features 3
Specifications 5
Installation & setup 6
Connect 12V power source 6
Connect the USB 6
Start the EMUS BMS Control Panel 7
Configure cell count and type 8
Install Cell Modules 9
Connecting Charging and Battery low indication 13
Connecting sound buzzer 13
Connecting Ignition and Fast charge input switches 14
Connecting non-CAN charger 14
Connecting CAN charger 15
Connection of IPAQ as display unit 16
Cell temperature calibration 16
Cell voltage configuration 17
Configuring the charger 19
Configuring the timing 20
Firmware updates 22

Introduction

Recent development of rechargeable battery technology allowed wider use of electric propulsion in electric vehicles, electric motorcycles, boats etc. Most popular high performance batteries are based on Lithium chemistries. Such batteries require systems to keep them in the specified usage range while being used. The Battery Management System (BMS) is required for batteries that are sensitive to their usage conditions such as current, voltage and temperature. EMUS BMS is the product intended for use with LiIon, LiPO, LiFePO4 and other chemistries prismatic battery cells which operating voltages range is from 2V to 5V. EMUS BMS is a distributed type of digital BMS with central Control Unit. It does the balancing of the cells by dissipating the excess energy of cells as heat which is often referred to as passive balancing.

It's usage is explained further in this manual.

System structure

EMUS BMS is designed for batteries where cells are connected in series to form a higher voltage battery pack. Each cell of the battery has a Cell Module which monitors cell's parameters, controls the balancing current and communicates with central Control Unit over 1 wire digital interface.

EMUS BMS Control Unit is connected to Cell Modules via double twisted-pair optically isolated interface over which it communicates and collects cell characteristic information and manages the battery. Control Unit also connects to charger via CAN bus or via Solid State Relay (SSR) if non-CAN charger is used. Collected data is sent via serial RS232 interface and CAN bus. The data can be gathered and displayed to the user by Display Module (optional add-on). Control Unit also has a USB interface for firmware updates, configuration, which is used to connect it to a PC to configure the BMS via special EMUS BMS Control Panel software.

EMUS BMS Control Unit also has a connection to Current Sensor Module (optional add-on) which enables the EMUS BMS to act as a State Of Charge (SOC) meter allowing user to monitor remaining battery charge and plan a trip or operation. To allow such trip planning there is an input for vehicle Speed Sensor signal.

Control Unit connects to other user controls as well: Ignition Key and Slow/Fast charge selection switch. Several output connections are intended to be used as audio-visual indicators to the user: Charging and Low Battery indicators and warning audio buzzer.

Standard package contents

1. EMUS BMS Control Unit – 1 unit
2. EMUS BMS Cell Module, one per cell:
   a) Cell Module of “Bottom” type - 1 unit
   b) Cell Module of “Top” type - 1 unit
   c) Cell Modules of A and B type - number as per customer's requested number of cells, minus 2 units
3. Cell Module inter-connection wires, pre-cut and ready to use - number as per customer's requested number of cells
4. EMUS BMS Control Unit's 22-pin connection header with contacts - 1 unit
5. 120 Ohm CAN termination resistor - 1 unit

Features

- Suitable for wide range of battery chemistries with operating voltage 2 to 5 V per cell (LiPO, Li-Ion, LiFePO4 and others).
- Fully scalable: 2 to 255 cells, 8 to 1300 Volts battery pack.
- Measures voltage of each cell in real time.
- Measures temperature of each cell in real time.
- Controlled balancing current of each cell.
- Configurable maximum balancing current up to 1.5 A.

- Configurable minimum cell temperature for charging (typically 0°C for lithium cells).
- Battery heater control: the EMUS BMS will pre-heat the battery before charging, if configured to.
- Full charger control: ON/OFF and AC sense for conventional chargers, full charge characteristics for CAN chargers, slow/fast charge modes.
- Load control: switches off the load when critically low voltage is reached on any of cells.
- State-Of-Charge (SOC) indication: conventional analogue gauge or LCD with statistical information (requires optional add-on).
- Additional indication: „Battery low“ light and buzzer, „Charging“ light.
- USB-configurable: free EMUS BMS Control Panel application for Windows OS is supplied to update the firmware of the EMUS BMS, configure it, read statistical data and observe each cell in real time.
- One-wire digital interface between Cell Modules: the minimum of wires used, lowest risk of mechanical wire failure.
- Optically isolated interface between EMUS BMS Control Unit and Cell modules: no risk of electric shock.
- Forward-Error-Correction: greatly improved data transfer liability even in harsh EMI environments.
- Moisture resistant: the EMUS BMS Control Unit is hermetically sealed and the Cell Modules are treated to resist any moisture.
- Easy and tool-less installation: the only tool needed to install the Cell Modules is a wrench for your battery cell tabs. Once the Cell Module is connected, it starts to blink a green LED to indicate a live communication with the Control Unit – speeds up the installation process.
- Engineered and manufactured in European Union.

Specifications

Parameter	Value
Control Unit supply voltage	8 – 20 V
Battery pack voltage	4 – 1300 V
Series cell count	2 – 255 pcs.
Cell operating voltage	2 – 5 V
Cell balancing current	1.5 A
Balancing type	Passive/dissipative
Power consumption of the Control Unit	50 mA

Installation & setup

The installation of BMS is covered in the following chapters as step by step guide.

Connect 12V power source

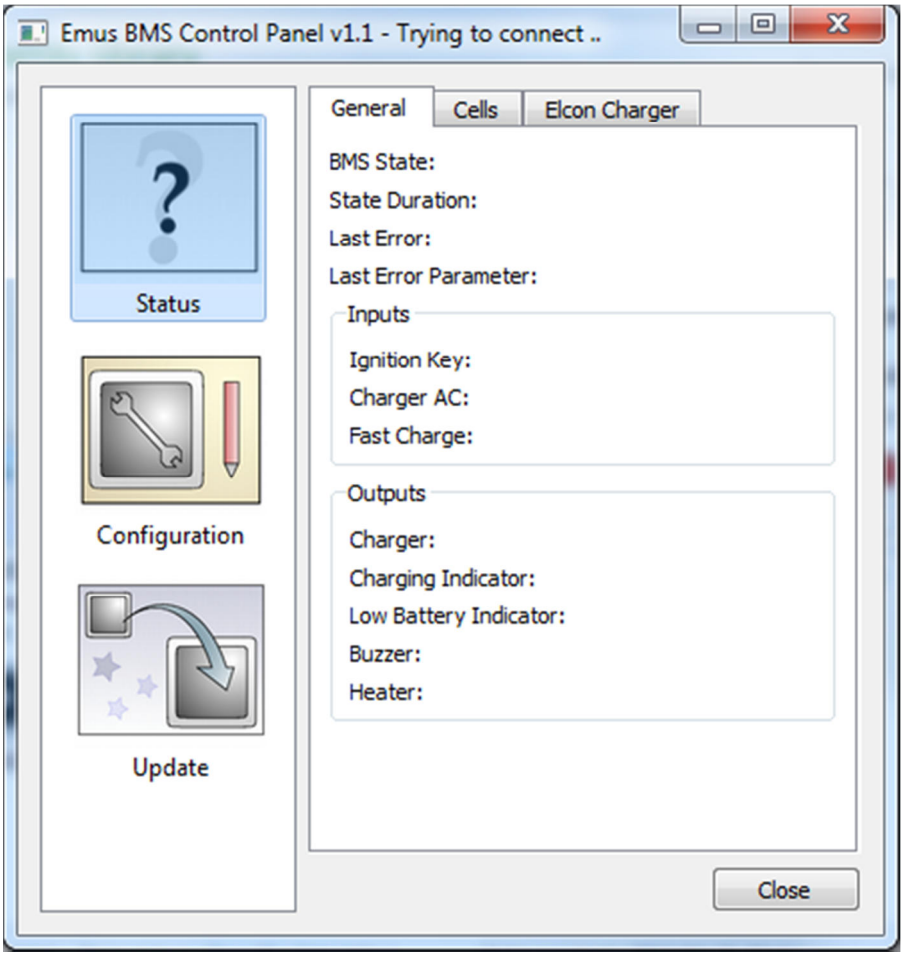
The EMUS BMS Control Unit needs 12 Volts DC power from vehicle's auxiliary battery or other 12V source. Connect 12V battery's negative (-) tab to “GROUND” and battery’s positive (+) tab to “+12V” wires of the 22-pin connector on EMUS BMS Control Unit.

Connect the USB

To verify basic EMUS BMS operation, connect the EMUS BMS Control Unit's USB socket to a Windows PC via mini-USB cable. Please use the drivers for your version of Microsoft Windows from USB Flash drive which is supplied with EMUS BMS or download them from FTDIChip site http://www.ftdichip.com/Drivers/VCP.htm. Make sure that a new device is found and is installed successfully without errors.

Start the EMUS BMS Control Panel

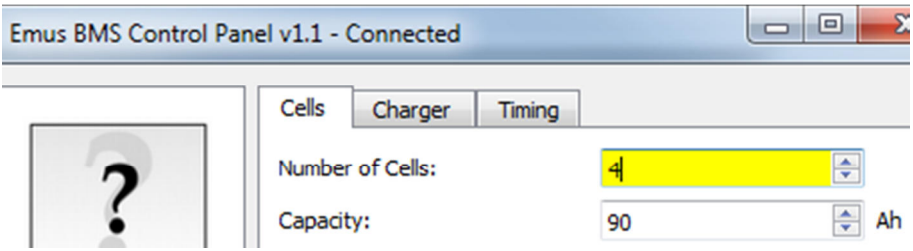
EMUS BMS Control Panel software application can be found on USB Flash drive supplied with the EMUS BMS or downloaded from our website www.elektromotus.eu. When started, application will initiate a connection to the EMUS BMS. When connected, EMUS BMS Control Panel application will indicate “*Connected*” on the title bar and show some basic BMS status parameters.



Cells tab will indicate the *Number of Cells* is “*0*” as you don't have any cells and Cell Modules connected to your Control Unit yet.

Configure cell count and type

The connection of the cells will be covered in the next chapter, but before that we will configure the number of cells for EMUS BMS that it would expect to see on the battery after installation. The *Number of Cells* is configured by selecting *Configuration page* and *Cells* tab. In our example we enter *Number of Cells* equal to 4 for demonstration purposes.

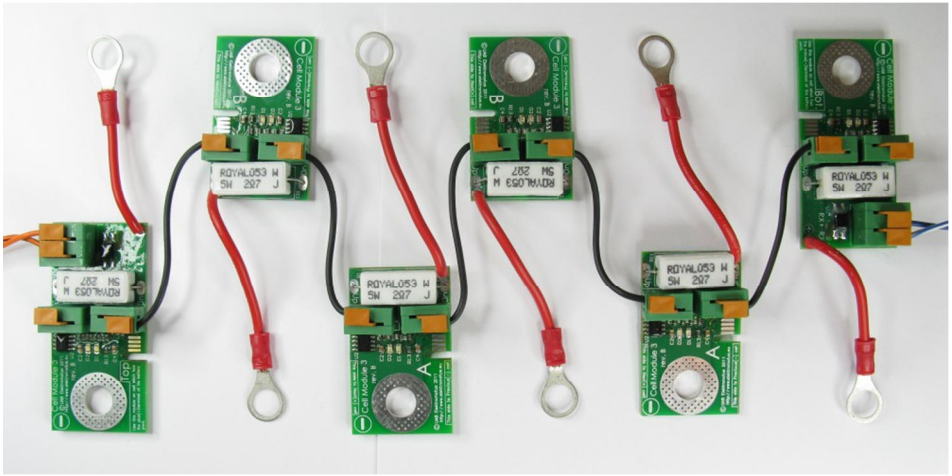


In the *Number Of Cells* field, specify the amount of series cells in the battery pack. Cells can be connected in series and parallel configuration, for example 16 series and 3 parallel. Only a number of series cells should be specified here. Note how the *Number of Cells* field background color changes to yellow which indicates that the parameter is updated, but has not been written into EMUS BMS Control Unit yet. When you press Tab key or select other parameter field the color changes back to white, which means that parameter has been written to BMS.

In the *Capacity* field, enter a rated cell’s capacity in Amp-hours, specified in manufacturer’s datasheet. If multiple cells are used in parallel, specify a total capacity here. For example, three parallel cells of 100 Ah is a total of 300 Ah. Change all other parameters as per your requirements.

Install Cell Modules

There are 4 types of EMUS BMS Cell Modules to allow nice and tidy installation on the battery pack: Bottom, types A and B, Top. The type of the module is printed on the module itself. Bottom cell module is dedicated to be installed on the cell which has negative (-) terminal of the whole battery pack. Top module is installed on the cell which has positive (+) terminal of the pack. Type A and B modules are installed on the cells in between, as illustrated below.



HINT: it is recommended to start the installation of the modules from the Bottom Cell Module, connect it to the Control Unit and go up the battery stack installing other modules up to the Top one. This is because when starting from Bottom module which is connected to powered-up Control Unit you should see green LED flashing once every second indicating that cell module connection is OK. Then going up every next Cell Module connected to the chain should start flashing as well.

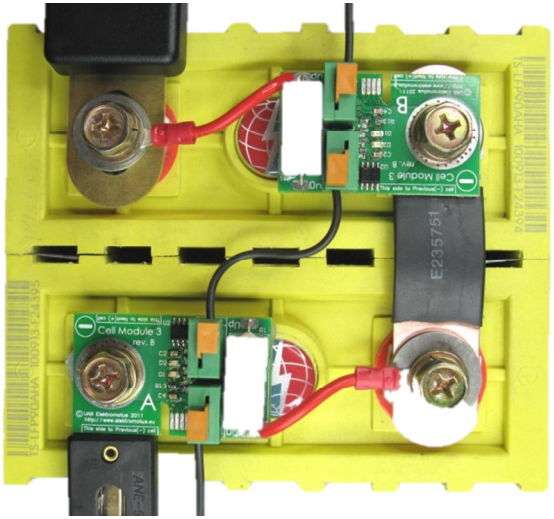
Bolt a Cell Module on the cell in the following scheme:

1) Cells inter-connection bus-bar.
2) Washer
3) EMUS BMS Cell Module
4) Washer
5) Spring washer
6) Bolt

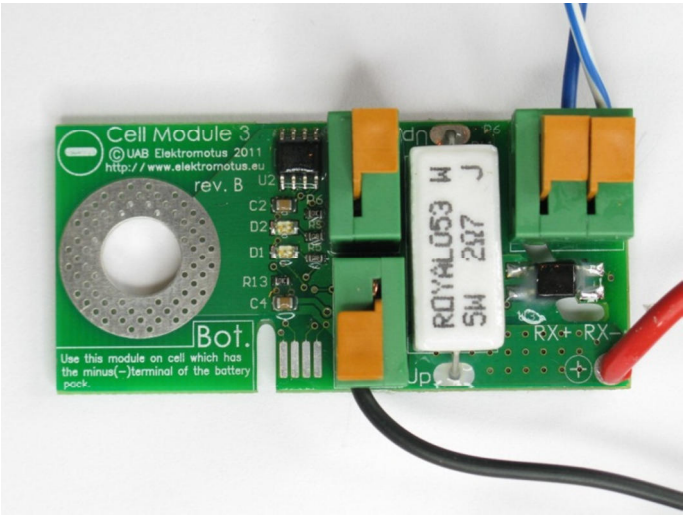
This applies both for EMUS BMS Cell Module itself (negative (-) contact) and it‘s red wire (positive (+) contact).

WARNING: Please pay special attention to the cell and module’s polarity! Cell Module must be bolted onto cell's negative (-) terminal and module’s wire must be bolted onto positive (+) terminal of the cell. Connection in reverse order even for a short period of time will result in Cell Module damage! This type of Cell Module failure is not covered by warranty.

Connect the data line wire between the Cell Modules. Connections of signal wires can be easily done without tools, by pushing back spring-loaded lever and pushing a bare end of the wire to the end into a hole of connector. The connectors have markings next to them showing “Dn” and “Up”. “Up” means upward direction i.e. going to next module in the stack towards positive (+) terminal of the battery pack, starting from the bottom (-). “Dn” means opposite downward direction, towards negative (-) terminal of the battery pack. Connect the “Up” signal of lower adjacent cell to “Dn” signal of upper adjacent cell. The type A and B modules have opposite directions of “Up” and “Dn” signals outputs to allow neat installation of short signal wires on the battery stacks which are formed in zig-zag configuration, as shown below (* mounting hardware and fuse are not included).

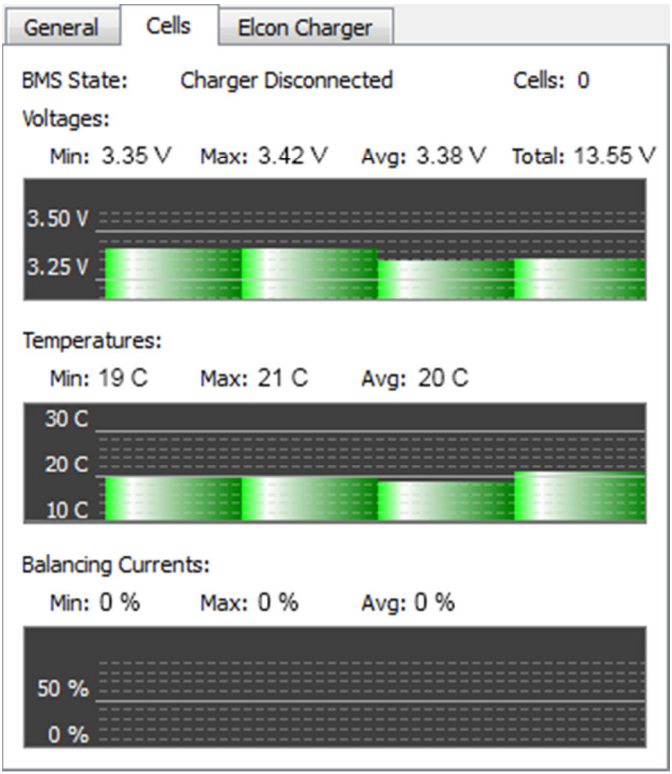


Bottom and Top Cell Modules have additional connections that go to EMUS BMS Control Unit:



Bottom Cell Module's “RX+” and “RX-” signals should be connected via twisted pair to Control Unit's “CELL RX+” and “CELL RX-” wires correspondingly. It is

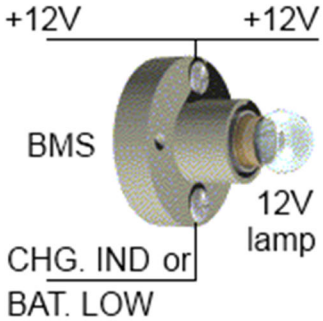
recommended to use shielded twisted pair cable whose shield is connected to “GROUND” of the EMUS BMS Control Unit. Top Cell Module's “TX+” and “TX-must be connected to “CELL TX+” and “CELL TX-” accordingly. Once all Cell Modules are installed and connected, the EMUS BMS Control Unit should be able to detect the cells. The EMUS BMS Control Panel's *Cells* status tab should show correct number of cells of the stack and their parameters in the graphs. Below illustration shows the view of 4 cells stack.



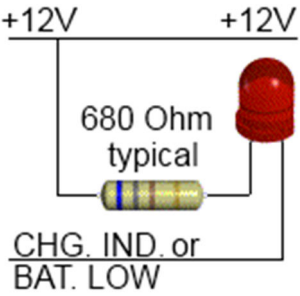
If you see something similar then you've completed your Cell Modules installation!

Connecting Charging and Battery low indication

EMUS BMS has two outputs for indication lamps “*Charging Indication*” and “*Battery Low*” which can provide basic EMUS BMS operation indication if the graphical display is not used. The outputs are pulled low to the ground when active. The Control Unit's outputs for lamps can provide up to 0.5 A current which allows to use up to 6W 12V lamps. LEDs can also be used but they must be connected with corresponding value resistor in series.

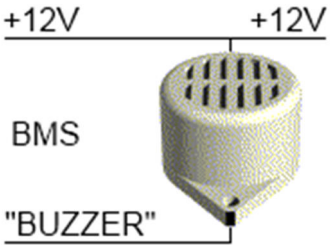


OR



Lamp's one terminal or LED's “-” side must be connected to EMUS BMS Control Unit's output. Other lamp's terminal or LED's “+” side must be connected to +12V external power source. The source could be the same as supplying the power to BMS.

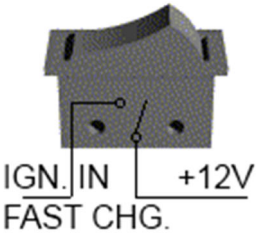
Connecting sound buzzer



The warning buzzer must be of self-oscillating type which emits a sound of some warning frequency when it is connected to power source of 12V. The output is pulled low to the ground when active. Buzzer's (-) terminal must be connected to Control Unit's *„BUZZER*” output. Buzzer's (+) terminal must be connected to +12V power source. The buzzer may draw up to 0.5 A current maximum.

Connecting Ignition and Fast charge input switches

EMUS BMS inputs “*IGN. IN*” and “*FAST CHG.”* are activated by positive +12V signals. “IGN. IN” should be connected to vehicle's ignition key switch which supplies +12V when active. This input informs the EMUS BMS when the vehicle is being actively used.



“*FAST CHG.”* should be connected to two position switch which is supplying +12V when fast charging mode is selected.

Connecting non-CAN charger

Non-CAN charger does not have the benefits of CAN charger but may also be used with EMUS BMS. There are two signals provisioned for such charger connection: “*AC SENSE*” and “*CHARGER*”.

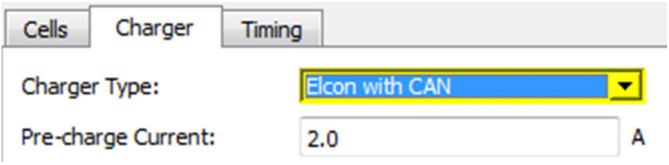
“*AC SENSE*” is the input which senses the charger connection to AC mains power source. +12V voltage applied on this input informs BMS that charger was connected to AC mains socket and charging can start.

“*CHARGER*” is the output controlling the charger. It is pulled low to the ground when active. It may drive charger's input or a relay which is connecting the AC power source to charger's input.

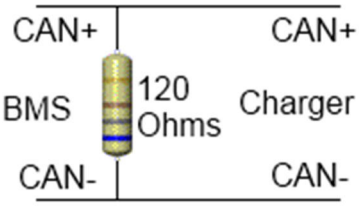
An optional specially designed opto-isolated AC sensing non-CAN charger control relay can be ordered from JSC “Elektromotus”. This relay connects to “AC SENSE” and “CHARGER” signals on low voltage side. On high voltage side it connects to AC mains source and charger's AC input.

Connecting CAN charger

Before connecting CAN charger a correct charger model must be selected in *Charger Type* field via EMUS BMS Control Panel application on PC.



The connection to CAN charger is made by connecting EMUS BMS Control Unit's CAN+ and CAN- signals to corresponding charger's CAN interface signals.



Resistive termination is required for reliable operation of CAN interface. EMUS BMS Control Unit does not have internal terminator between CAN+ and CAN- signals. If charger does not have internal termination then external 120 Ohm termination resistor must be connected between CAN + and - signals. The 120 Ohm termination resistor is included in the EMUS BMS package.

Once the CAN charger is properly connected to Control Unit via CAN bus it may be verified by plugging it into AC mains. EMUS BMS Control Unit will detect the powered-up charger via CAN bus and start a charging process which can be checked by *Charging Indication* lamp, graphical display or via EMUS BMS Control Panel application on PC.

Connection of IPAQ as display unit

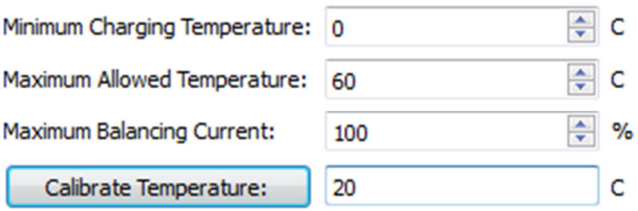
EMUS BMS Control Unit sends its output parameters via serial RS232 interface. This data can be used for detailed display of BMS operation details via graphical user interface using various graphical handheld devices.

Free open-source software IPAQ EV GUI for IPAQ series handheld devices is available on www.elektromotus.eu website. IPAQ devices of various series which have serial interface and are running Windows Mobile operating system can be used. Software is currently available for ARM processor platform based IPAQ devices but could be expanded to broader range in future.

When connecting IPAQ the EMUS BMS Control Unit's “*DISP. TX*” should be connected to IPAQ's „RX“ data line and „*DISP. RX*“ should be connected to IPAQ‘s „TX“ data line.

Cell temperature calibration

EMUS BMS measures temperatures of each cell – each of EMUS BMS Cell Modules have temperature probes. These probes require initial calibration to work properly. When all battery cells and EMUS BMS Cell Modules are installed, user must initiate a temperature calibration command. To do so, connect the EMUS BMS Control Unit to PC’s USB port, start the EMUS BMS Control Panel application and navigate to *Configuration* page, *Cells* tab. There you will find a *Calibrate Temperature* button and empty field next to it. Type in a current temperature of the battery pack and click the button. Ordinary household thermometer is sufficient for getting this reference temperature. Use this calibration only when all cells are at the same temperature.

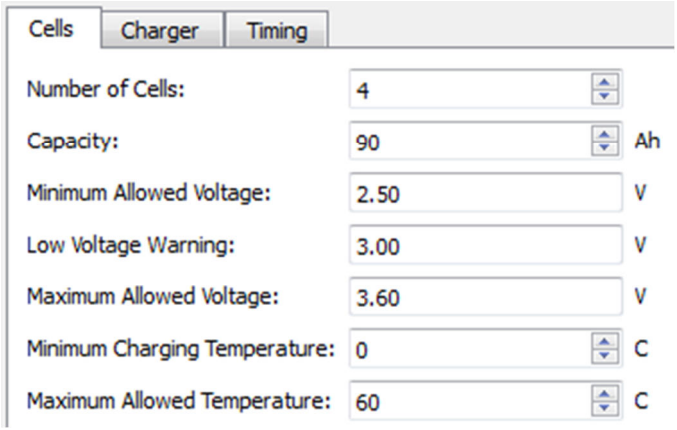


This will set the temperature of all cells to the one specified. The result can be checked at *Status* page, *Cells* tab, *Temperatures* graph.

Cell voltage configuration

EMUS BMS is designed to work with wide range of battery cells with operating voltages in between 2 and 5 V, including LiPO, Li-Ion, LiFePO4 and others. Different cell types operate at different voltages and these parameters must be set for proper operation of EMUS BMS.

To configure cell type, connect the EMUS BMS Control Unit to PC’s USB port, start the EMUS BMS Control Panel application and navigate to *Configuration* page, *Cells* tab.



Minimum Allowed Voltage and *Maximum Allowed Voltage* parameters are listed in cell manufacturer’s datasheet. Standard values for LiPO and Li-Ion cells are 3.0V and 4.2V respectively; for LiFePO4 – 2.5V and 3.6V. Usually higher-end LiFePO4 cells handle wider voltage swing – from 2.0V to 3.65V, but these values are not recommended for unknown cells.

Low Voltage Warning is a voltage threshold at which alarm (light/buzzer) will start during discharge state (when driving, operating, etc.). This value highly depends on battery cell type and manufacturer and should be chosen from

discharge graph in manufacturer’s datasheet. Usually for Li-Ion/LiPO cells it is around 3.6V and for LiFePO4 – around 3V. To get the warning sooner, increase this value.

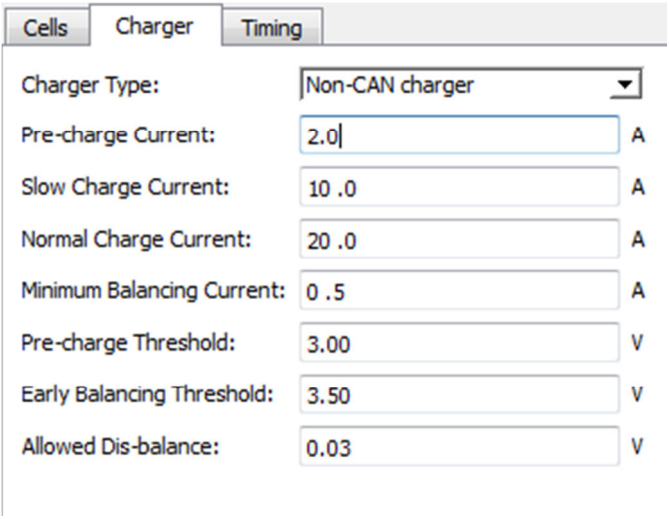
Minimum Charging Temperature depends on battery type as well. For most lithium cells, charging should be done in above-zero temperatures. To be on the safe side, set a value of, say, 2°C, to give it a little margin of error. EMUS BMS will turn on the battery heater (if one exists) and wait until cell temperatures reaches the value set, before charging the pack. To disable preheating and charge delay, enter a value of -100°C.

Maximum Allowed Temperature depends on battery type as well. For most lithium-based cells it is around 60°C. This value is not a strict one, but hence that the higher the temperature, the shorter battery life is. Usually LiFePO4 cells start to degrade much faster when used at temperatures above 45-50°C and most LiPO/Li-Ion cells, in addition to shorter life, can catch fire if operated above 60°C. If any cell in the battery pack reaches specified temperature, load and charger are disconnected and error code shown. Use this setting responsibly.

HINT: Cell temperature probe is situated on Cell Module itself and does not represent an accurate temperature of the cell. Cell tabs do have a good inner thermal conductivity and, usually, Cell Module will report a bit lower temperature, especially at high values. Also keep in mind that Cell Module heats up during balancing stage and reported temperature will be higher than actual.

Configuring the charger

To configure timing of the EMUS BMS, connect the EMUS BMS Control Unit to PC’s USB port, start the EMUS BMS Control Panel application and navigate to *Configuration* page, *Charger* tab.



Charger Type dropbox selects a type of charger: with or without CAN interface. Please note that following current settings are applicable for CAN charger only.

Pre-charge Current field sets a current for pre-charge mode. This mode is active when voltage at any of the cells is lower than the value specified in *Pre-charge Threshold* field. This field is applicable only for CAN charger.

Pre-charge Threshold field specifies lowest operating voltage of the cells. Typically this value is 3.0 V for LiPO/Li-Ion cells and 2.5 V for LiFePO4. The exact value should be specified in cell manufacturer‘s datasheet. This field is applicable only for CAN charger.

Slow Charge Current sets a charging rate for charging the vehicle prom lower power, often public outlets. If, for example, the outlet is limited to 1 kW and

your cell voltage is 100 V, then *Slow Charge* Current should be set to 10 A (1 kW/ 100 V = 10 A). This field is applicable only for CAN charger.

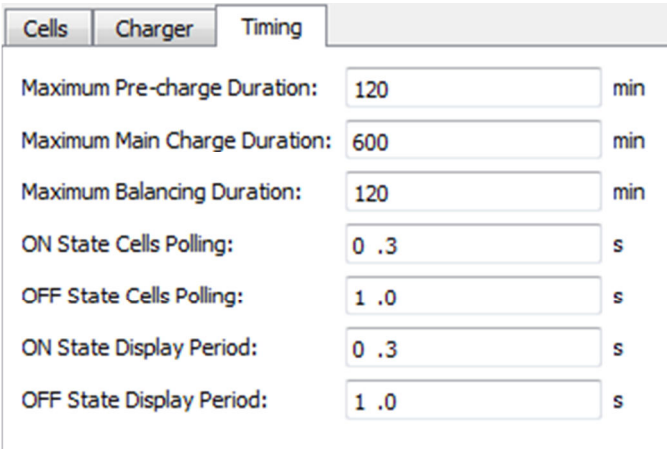
Normal Charge Current value should be set according to combined ability of the cells, charger and power outlet, whitch one is the lowest. If, for example, the charger can give a 50 A current, but battery cells are 100 Ah and rated at only 0.3 C charge rate, this is a limiting factor and *Normal Charge Current* value should be set to 30 A (100 Ah * 0.3 C = 30 A). This field is applicable only for CAN charger.

Early Balancing Threshold value sets a minimum cell voltage at which cell balancing starts. By lowering this value faster balancing and overall charge time can be achieved, but this increases power losses, dissipated as heat in Cell Modules. Usually threshold of 3.4 V is optimal for LiFePO4 cells and 3.7 V for LiPO/Li-Ion cells.

Allowed Dis-balance value sets the minimum difference between cell voltages at which it is considered that cells are at balance and cell balancing is turned off.

Configuring the timing

To configure timing of the EMUS BMS, connect the EMUS BMS Control Unit to PC’s USB port, start the EMUS BMS Control Panel application and navigate to *Configuration* page, *Timing* tab.



Maximum Pre-Charge Duration specifies the amount of time for the EMUS BMS to try to pre-charge cells up to *Minimum Allowed Voltage*, (specified in *Cells* tab) if the battery pack is over-discharged. If this phase takes longer than a couple of hours it may indicate a *Cell Module* malfunction of a bad cell.

Maximum Main Charge Duration specifies the amount of time for the main charge phase. If, for example, total cell capacity is 100 Ah and the pack is being charged with current of 20 A, the pack should be fully charged in 5 hours. Give it a bit of reserve and set, say, 7 hours (420 minutes). Too long charging time may indicate a bad cell and big energy leak (heat) in the battery pack. If the problem occurs, check cell voltages on *Status* page, *Cells* tab.

Maximum Balancing Duration specifies the amount of time for cell balancing. If cells are taking long to balance, this may mean a big difference in cell characteristics and one or more cells should be replaced to match the pack.

ON State Cells Polling sets the rate at which Cell Module data is being read in active mode (when ignition key is ON and charger is ON).

OFF State Cells Polling sets the rate at which Cell Module data is being read in idle mode (when ignition key is OFF and charger is OFF).

ON State Display Period sets the rate at which data is being sent to graphic display in active mode (when ignition key is ON and charger is ON). This value should be equal to or higher than *ON State Cells Polling.*

OFF State Display Period sets the rate at which data is being sent to graphic display in idle mode (when ignition key is OFF and charger is OFF). This value should be equal to or higher than *OFF State Cells Polling*. Backlight of the graphic display is turned off in idle mode.

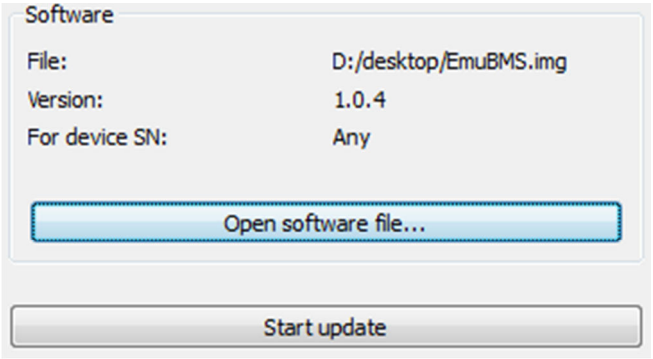
Firmware updates

EMUS BMS is controlled by a microprocessor, which is running a firmware. The firmware is just like any other piece of software – it can be updated to a new version, which may have bugfixes and new features.

Newest firmware version can be downloaded from manufacturer‘s website at www.elektromotus.eu. Once a new firmware image (*.img) file is downloaded, save it on your desktop.

To update the EMUS BMS, connect the EMUS BMS Control Unit to PC’s USB port, start the EMUS BMS Control Panel application and navigate to *Update* page.

In *Device Information* section, information about your device is displayed: *Software Version* and *Serial Number*. Click on *Open software file* button, navigate to Desktop and open the firmware image file.



File information appears in *Software* section. If versions of the file and firmware running in the EMUS BMS Control Unit are the same, it is up to date and does not need an update.

To start the update, click on *Start update* button and wait until update process completes and successful firmware update is confirmed.

This is the end of setup guide. Your EMUS BMS should be now up and running.

We expect that you will enjoy our product and we welcome your feedback at info@elektromotus.lt.

More products EMUS brand products can be purchased from JSC “Elektromotus”. Please visit our website: www.elektromotus.eu